

# OBSERVATIONS ON EGYPTIAN HYALOMMA TICKS (IXODOIDEA, IXODIDAE).

## 5. BIOLOGICAL NOTES AND DIFFERENCES IN IDENTITY OF H. ANATOLICUM AND ITS SUBSPECIES ANATOLICUM KOCH AND EXCAVATUM KOCH AMONG RUSSIAN AND OTHER WORKERS. IDENTITY OF H. LUSITANICUM KOCH<sup>1</sup>

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### ABSTRACT

Exhaustive study of very considerable material confirms the opinions of the Pomerantzev school that (1) *Hyalomma anatolicum* Koch and *H. excavatum* Koch are taxonomically valid subspecies (of *anatolicum*), (2) the subspecies *anatolicum* is that which non-Soviet workers have been referring to as *H. excavatum*, sensu Delpy, and (3) the subspecies *excavatum* is that which non-Soviet workers have been calling *anatolicum*, sensu Delpy. The immature stages of the subspecies *excavatum*, which differ morphologically from those of *anatolicum*, feed on rodents, rabbits and hares, whereas those of *anatolicum* generally feed on larger domestic animals. The former subspecies breeds actively during the winter months (in North Africa, at least), while the latter usually undergoes a winter diapause. These forms, which rank high among the world's economically most important ticks, range from southern Europe and northern Africa through the Near and Middle East to the Indian sub-continent. Narrowly elongate samples from populations at the eastern end of this range suggest the presence of yet another subspecies in this area (rearing experiments to determine their status presently underway will require

a year or more for completion). *H. a. anatolicum* is usually more numerous than *H. a. excavatum* and is more uniformly distributed, while *excavatum* is absent in certain ecological zones where *anatolicum* is present. Intergradation is nil in most areas, but ranges from 2 to less than 20 percent among certain Mediterranean littoral populations of Egypt and Libya. Movements of domestic animals appear in some areas to break down partially the ecological isolation of the two forms. The subgenus *Hyalommina* Schulze, 1919, and the species *H. rhipicephaloides* Neumann, 1901, are regarded as synonyms of *Hyalomma* and of *H. anatolicum*, respectively; subgenus *Delpyiella* Santos Dias, 1956, erected for the Indian *H. hussaini* Sharif, is found to be valid. *Hyalomma lusitanicum* Koch, 1844, synonymized with *H. anatolicum* by many workers, is found to be a valid species occurring in southwestern Europe, the Canary Islands, and Morocco. Morphological and biological characters of the recently recognized *H. franchinii* Tonelli-Rondelli, 1932, are compared with those of the *anatolicum* complex, for which keys to males and females are provided.

The present report presents findings resulting from taxonomic and biologic studies of the form referred to as *Hyalomma* species number 2 near *excavatum* by Hoogstraal (1956). Review of Soviet literature and comparative study of specimens in the Schulze and in several other collections, including some sent to us by Russian workers, reveal that the names *H. anatolicum* (or *H. a. anatolicum*) and *H. excavatum* (or *H. anatolicum excavatum*) have long been used in exactly the reverse sense by Russian and non-Russian students. A vast amount of medical and veterinary literature deals with the two subspecies in the U.S.S.R. and elsewhere; these concern Uzbekistan hemorrhagic fever, various other encephalitic viruses, Q fever, theileriasis, piroplasmiasis, etc. It is, therefore, especially desirable to be certain of the application of specific and subspecific names of the ticks involved as reservoirs or vectors in Europe, Africa, and Asia.

From Kratz's (1940) and Feldman-Muhsam's (1954) descriptions, measurements, and illustrations of the type specimen of *H. excavatum* Koch, it is evident that the Pomerantzev school has

been correct in referring to the larger-size, less common subspecies of *H. anatolicum* as *excavatum* (sensu Pomerantzev, not Delpy). The smaller-size, more common subspecies, *excavatum* of Delpy, Feldman-Muhsam, and the writers therefore now becomes *H. a. anatolicum* (sensu Pomerantzev, not Schulze). Although this reversal undoubtedly will cause some temporary taxonomic turmoil, it does not affect the bulk of significant literature references to these two forms, which are largely in Russian publications owing to these ticks' ubiquity and economic importance there.

Unless otherwise indicated, the names *anatolicum* and *excavatum* are used sensu Pomerantzev throughout the present paper.

The synoptic lists in the following text include only those names from more important generic reviews and others that we are now certain are synonymous. During the past decade the enormity of earlier indiscriminate naming of species, subspecies, and sub-subspecies in this genus has been equalled by similarly indiscriminate, whimsical lumping of names for biologically and morphologically distinct populations by reviewers who failed to obtain representative samples for comparative study.

All material noted herein was collected by one or both of the writers, presented by various

<sup>1</sup>Research Report NM 52 08 03.12. The opinions and assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large. Accepted for publication July 28, 1958.

colleagues (NAMRU-3), or studied by them for the Rocky Mountain Laboratory (RML), and the British Museum (Natural History) (BMNH).

### *Hyalomma (Hyalomma) anatolicum anatolicum*

Koch (= *H. excavatum* of Delpy and non-Soviet workers)

#### The Small *Hyalomma*

(Figures 1-12, 27)

*Hyalomma anatolicum* Koch, 1844, pp. 220-221; short description of ♀ only; type locality "Kleinasien" (i.e., eastern Turkey).

*H. anatolicum* Koch; Koch, 1847, pp. 13, 35-36, Plate 3, Fig. 9, ♀ redescribed and illustrated.

*H. rhipicephaloides* Neumann, 1901. A considerable amount of evidence indicates that representatives of this "species" are no more than abnormal specimens of *H. a. anatolicum*. See below.

*H. anatolicum* Koch; Schulze and Schlottke, 1930. Key only. Various forms synonymous with *excavatum* (sensu Delpy) keyed; for list see Tendeiro (1956, pp. 386-390) and remarks below.

*H. excavatum* Koch; Kratz, 1940, p. 529, synonymizes *H. excavatum* under *H. anatolicum* Koch. Description of *H. anatolicum* (pp. 529-530) is obvious mixture of both subspecies, *anatolicum* and *excavatum*, and of *H. lusitanicum*. On p. 531 reports the Koch type of *H. anatolicum* to be missing from the Zoological Institute of Munich but "those . . . of *excavatum* Koch in the Zoological Museum in Berlin"; notes especially large depressed caudal field and incomplete pons over the white parma in these specimens [the latter is an important characteristic of this subspecies, which together with the measurements and further description of Feldman-Muhsam (1954) definitely establish the identity of this form].

*H. savignyi* subsp. Kratz, 1940, pp. 532-536; most, though not necessarily all, of these forms (i.e., *H. savignyi* subsp., and *H. tunesiacum* subsp.) are synonymous with *H. anatolicum* subsp.

*H. anatolicum anatolicum* Koch; Pomerantzev, 1946, pp. 24 and 27, key descriptions of both sexes; the form referred to as *H. anatolicum excavatum* is equal to *H. anatolicum* (sensu Schulze).

*H. savignyi* (Gervais); Adler and Feldman-Muhsam, 1946, pp. 91-94; key to spp. in Palestine. Numerous papers by the latter author from 1947 to 1951 follow this terminology.

*H. excavatum* Koch; Delpy, 1946, pp. 288-293, and Delpy 1949A, pp. 103-108; key descriptions of both sexes. Delpy, 1949B, pp. 474-477, plates XIX and XX, redescrptions and illustrations of both sexes, and also synoptic lists, large parts of which represent indiscriminate lumping of species.

*H. anatolicum anatolicum* Koch; Pomerantzev, 1950, pp. 211-214, descriptions and illustrations of both sexes; biological data; this paper follows the systematic precedent set by Pomerantzev (1946), noted above.

*H. excavatum* Koch; Feldman-Muhsam, 1954, pp. 155-159; description, measurement, and illustration of Koch's type specimens; discussion; too-extensive list of synonyms.

*H. excavatum* Koch; Tendeiro, 1956, pp. 386-397; complete redescription and illustration of both sexes, literature review, synoptic lists.

*H. anatolicum* Koch; Serdyukova, 1956, pp. 79-84, key to species only.

*H. excavatum* Koch; Hoogstraal, 1956, pp. 435-451, 878-879, species review, including both subspecies.

*H. excavatum* Koch; Anastos, 1957, p. 149, literature review, including both subspecies.

Russian workers, commencing with Olenov in the 1930's, utilized the names *H. anatolicum*, *H. a. anatolicum*, and *H. anatolicum excavatum*. Not until Pomerantzev (1946, pp. 24-27, and 1950, pp. 211-214) was it possible definitely to determine exact species or subspecies in Russian literature. Most Soviet references between the late 1940's and 1954 follow the Pomerantzev system. Identified specimens presented to us in 1957 and 1958 by Russian workers conform exactly to Pomerantzev's descriptions and illustrations and to our own samples from Europe, Africa, and Asia. However, since Pervomaisky (1954) reverted to the opinion that this is a single, exceptionally polymorphic species (with which we cannot agree), Soviet workers have again dropped subspecific designations.

In order accurately to determine different authors' usage, we made a comparative study of material in the RML collections, including the Schulze collection, and in our collection, including Russian-identified specimens. We also again reviewed pertinent literature mentioned throughout this report. The results indicate beyond a doubt that: (1) *H. anatolicum anatolicum* (sensu Pomerantzev) is the form consistently referred to as *H. excavatum* by non-Soviet workers such as Delpy, Tendeiro, Feldman-Muhsam, the writers, and others during the past decade; and (2) *H. anatolicum excavatum* (sensu Pomerantzev) is the same form as *H. anatolicum* (sensu Schulze).

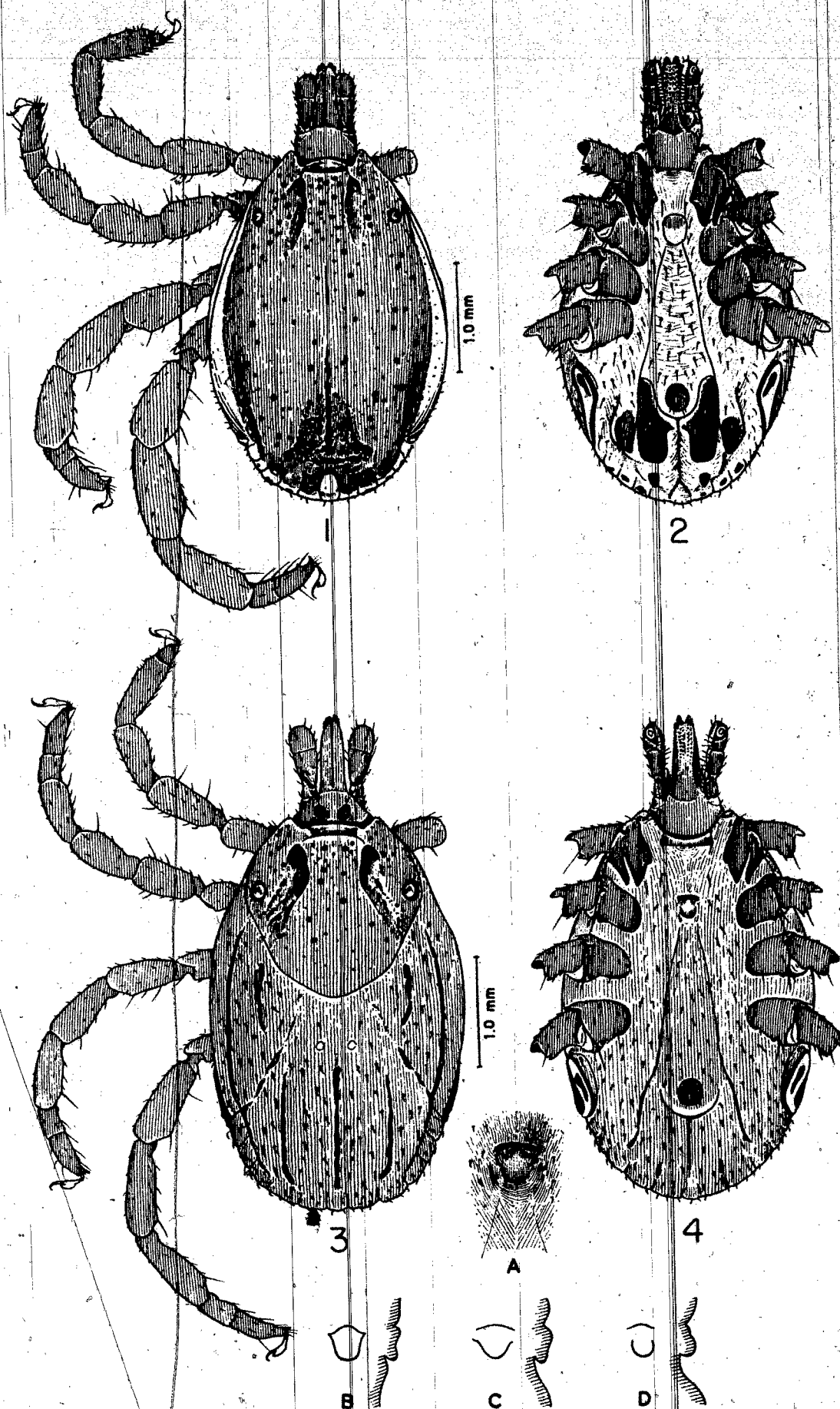
#### MATERIAL EXAMINED

For this study we have examined well over 10,000 specimens collected in nature in Canary Islands, Morocco, Algeria, Tunisia, Libya, Egypt, Sudan, Eritrea, Ethiopia, French Somaliland, Portugal, Italy, Palestine, Jordan, Syria, Lebanon, Turkey, Saudi Arabia, Trucial Oman, Aden, Iraq, Afghanistan, Iran, Russia, Pakistan, and India. We have also studied large series of specimens reared in the laboratory.

#### BIOLOGY AND DISEASE RELATIONSHIPS

*H. anatolicum anatolicum* has been so thoroughly reviewed in Hoogstraal (1956, pp. 435-451, 878-879) (as *H. excavatum*) that, except for the following comments and modifications, further details are not required here.

*Distribution and prevalence.*—Our previous summary of the distribution of this form (as *H. excavatum*) (loc. cit., pp. 437-441) stands, with the exception that it is now believed to be entirely absent in southeastern Europe, where it is replaced by *H. lusitanicum*. The same is also true in parts of or throughout Morocco and the Canary Islands. In Italy, *H. lusitanicum* is the common species except in the south (Sicily, Puglia, and Calabria) where *H. a. anatolicum* occurs (Professor O. Starkoff, personal communication). We know of no populations intergrading between *H. lusitanicum* and *H. anatolicum*.



FIGS. 1-4.—*H. anatolicum anatolicum* (sensu Pomerantzev). ♂ and ♀, dorsal and ventral, Egypt.

subsp.; therefore the former, with its distinct morphological criteria, merits full species rank. Restudy of tremendous collections of *H. anatolicum* subsp. leads us to believe that in almost every area where it occurs the subspecies *anatolicum* is more numerous and more uniformly distributed than the subspecies *excavatum*.

**Hosts and Biology.**—Collation of available data reveals that *H. a. anatolicum* seldom spends any part of its life cycle on animals smaller than hares. This fact has long been maintained by Russian workers. In North Africa, at least, all stages and both sexes, especially females, are strikingly rare on animals during the coldest months of the year. Both of these findings are in direct contrast to those for *H. anatolicum excavatum*, whose immature stages are known only from small insectivores and rodents and from hares, and all of whose stages are active at all times of the year but even more so (in North Africa, at least) in winter than in summer. After more systematic biological studies in other areas where the subspecies *anatolicum* occurs, various conclusions in the previous review (loc. cit., pp. 441-448) may or may not have to be modified.

**Remarks.**—In the previous review (loc. cit., pp. 448-449) notes concerning Schulze's theories of leg ornamentation and Yalvac's report from Kenya probably refer actually to the subspecies *excavatum* and not to *anatolicum*.

**Disease Relations.**—It appears that the following sections of the previous review (loc. cit., pp. 449-450) refer to the subspecies *excavatum* and not to *anatolicum*: (1) experimental work with "*H. turkmeniense*" on Russian spring-summer encephalitis and on Russian and Japanese mosquito-borne encephalitis viruses, and (2) experimental work on survival of spirochetes in Russia. Also, remarks concerning infection with *Coxiella burnetii* in southern Europe and in Morocco refer entirely or partly to *H. lusitanicum*.

#### IDENTIFICATION

The previous description of this form (loc. cit., pp. 450-451) stands except that most of the "atypical" specimens mentioned therein are now found to represent *H. anatolicum excavatum*. Owing to the fact that a neotype of *H. a. anatolicum* is reported in the present paper, this form is redescribed below.

**Males.**—Small, yellowish-brown ticks, with a convex, lightly punctated scutum; very short but distinct lateral grooves; a depressed punctate caudal field between two smooth ridges; a pronounced posteromedian groove not reaching the parma; small subanal shields directly posterior of adanal shields; legs yellowish, unstriped, rarely with faint pale markings, but not marbled when dry.

The scutum measures no more than 3.85 mm. in length and 2.33 mm. in width. Average specimens are 3.50 mm. in length and 2.00 mm.

in width, but smaller individuals and populations are common locally or seasonally. Typical color is yellowish brown becoming darker reddish brown on larger specimens. Cervical grooves are superficial, comparatively short, not extending beyond anterior third of scutum if that far. Lateral grooves are very short, deep, distinct, a row of closely spaced large and/or small punctations may continue anteriorly from them. The posteromedian groove is pronounced; it is separated from the parma by a group of warts or by a narrow smooth area. Paramedian grooves are rather superficial, bordering the inner side of the very slight lateral ridges bounding the depressed caudal area. The caudal field has large punctations, but these are few and non-contiguous, and small punctations. The smooth, convex scutum has very few large, widely spaced, shallow punctations and a varying number of superficial minute punctations; punctations are somewhat more dense between cervical grooves and on scapulae. The parma is a paler color than the scutum; it is almost invariably present. The pair of festoons bordering the parma (paraparmal festoons) are elevated and slightly extended anteriorly, the next pair end at the paramedian grooves, and the two lateral pairs are fused into the lateral ridges. Subanal shields (figures 5-12) are small to minute, usually elongate, not infrequently one or both are lacking (see below); they are borne directly posterior of the adanal shields but in either hugely engorged individuals or in freshly molted and preserved individuals they may be more or less laterally displaced on udderlike swellings. The legs are yellowish or pale brown, not striped, rarely with faint pale markings, not marbled when dry.

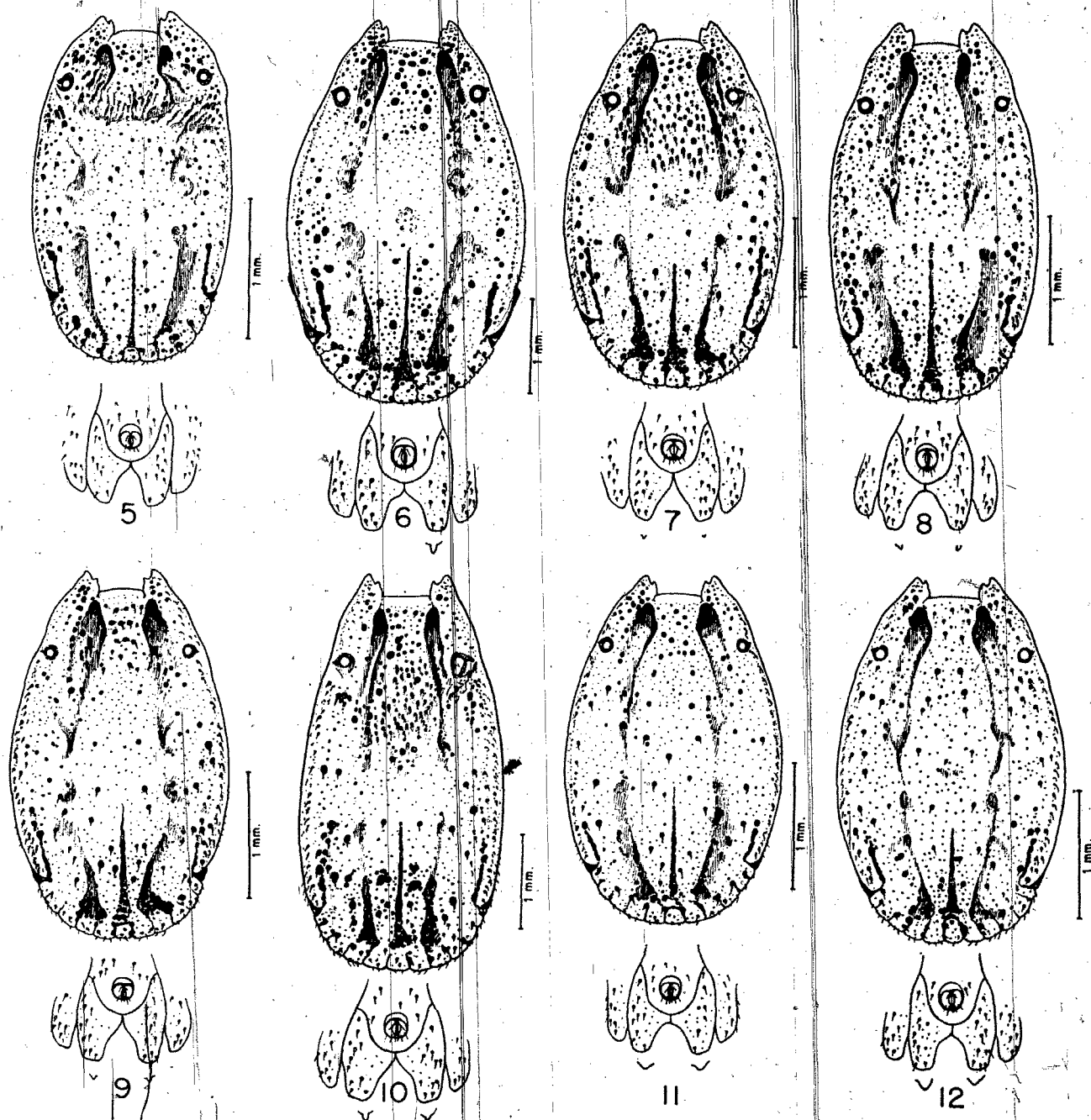
For intraspecific intergradation, see section below. Some populations, especially all of those that we have seen from India, are very small, measuring a maximum of 3.10 mm. in scutal length. Populations from far eastern Turkey (Lake Van), Caucasus (U.S.S.R.), Afghanistan, Pakistan, and India have exaggeratedly narrow scutums, measuring 3.60 mm. in length and only 1.95 mm. in width. It is strongly suspected that these may eventually prove to be a separate subspecies of the *anatolicum* complex. We have recently commenced rearing pertinent material to determine its biological and taxonomic status, an effort that will require at least a year to complete.

**Variation in subanal shields.**—Figures 5 to 12 lucidly illustrate variation in subanal shields of this subspecies. In figures 10 and 11, subanal shields are of normal size, in figure 12 they are somewhat larger than usual, in figures 7 to 9 they are minute to small, in figure 6 only one is present, and in figure 5, none is present. This small sample from a series of over 100 reared by the writers from nymphs from cattle at Ankara, Turkey, is representative of variation in numerous



large collections of *H. a. anatolicum*. Pomerantzev (1950, p. 214) has similarly noted that "among collections of *H. a. anatolicum* modified forms are frequently found with weak scutal shields and reduced anal shields and aprons; this phenomenon is observed chiefly in the Ararat valley of Armenia where this subspecies appears in masses." Specimens lacking subanal shields are also found in collections of *H. truncatum*, *H. marginatum*, and other *Hyalomma* species. Unfortunately, over-eager taxonomists with small samples to work with have applied species names to these abnormal individuals (see *Discussion* below).

*Females*.—The knoblike genital apron is always definitely bulging in profile; in outline it may be circular, elongately triangular, or (in greatly engorged specimens only) widely triangular (but if so, always distinctly smaller than in *H. marginatum* or similar species). The circular outline is most characteristic and distinctive; the elongately triangular outline is fairly common and usually fairly distinctive; the uncommon widely triangular outline may be confusing. Scutal color varies from yellowish brown to dark brown in larger specimens and is usually darkest in the scapular areas. The scutum, almost invariably



FIGS. 5-12.—*H. anatolicum anatolicum* (sensu Pomerantzev). ♂♂ scutums and associated posterior ventral surfaces to show variation in and absence of subanal shields. Material reared by authors at Ankara, Turkey, 1954, from nymphs from cattle.

longer than wide, measures a maximum of 2.00 mm. in length and 1.90 mm. in width; average specimens are 1.90 mm. in length and 1.71 mm. in width; the posterior margin is always narrowly rather than widely rounded. The scutum has few large punctations scattered in the central field, a few more in the scapular areas, and some to many very fine, superficial punctations over much of the surface. The legs are yellowish brown, either very faintly striped or unstriped. Typical engorged females are comparatively small and narrowly elongate but quite thick dorsoventrally, thus presenting a narrowly rectangular appearance.

## COMPARISON OF THE SUBSPECIES

*anatolicum* AND *excavatum**H. a. anatolicum*      *H. anatolicum excavatum*

## MALES

Small, frail, pale ticks; scutal length up to 3.85 mm., usually less, NEVER MORE

Color pale to pale reddish brown

Central punctations not deep

Caudal depression usually with some large punctations

Posteromedian groove separated from parma by narrow smooth or warty area

Ridges beside caudal field weakly elevated if at all

Adanal shields weakly chitinated, margins almost straight externally and rounded apically

Subanal shields elongate, weakly chitinated, often rudimentary or absent

Legs yellowish or pale brown, not striped, never marbled when dry

large, robust, dark ticks; scutal length 4.00 to 6.00 mm.; seldom less

reddish brown to dark brown deeper

with many small, seldom large punctations

bridgelike extension or usually fusion of paraparmal festoons

distinctly elevated

heavily chitinated, margins convex externally and usually rectangular apically

less elongate, heavily chitinated, seldom if ever rudimentary or absent

legs light brown, sometimes faintly striped, usually marbled when dry

## FEMALES

Scutal length less than 2.00 mm.

Color yellowish brown to brown

Genital apron outline circular or elongately triangular; widely triangular only when engorged

Scutum weakly chitinated, large punctations not deep

Legs faintly striped with pale yellowish-brown rings; never marbled

usually more than 2.00 mm.

reddish brown to dark brown

outline typically widely triangular, also may be circular or elongately triangular

heavily chitinated, large punctations deeper

faint reddish brown rings, usually marbled when dry

## BIOLOGY

Adults and immature stages seldom on hosts in winter (North Africa)

Immature stages chiefly on larger domestic animals or wild animals no smaller than hares

Distribution generalized

both sexes commonly on hosts in winter

known only from small insectivores and rodents, and hares

localized

## NEOTYPE

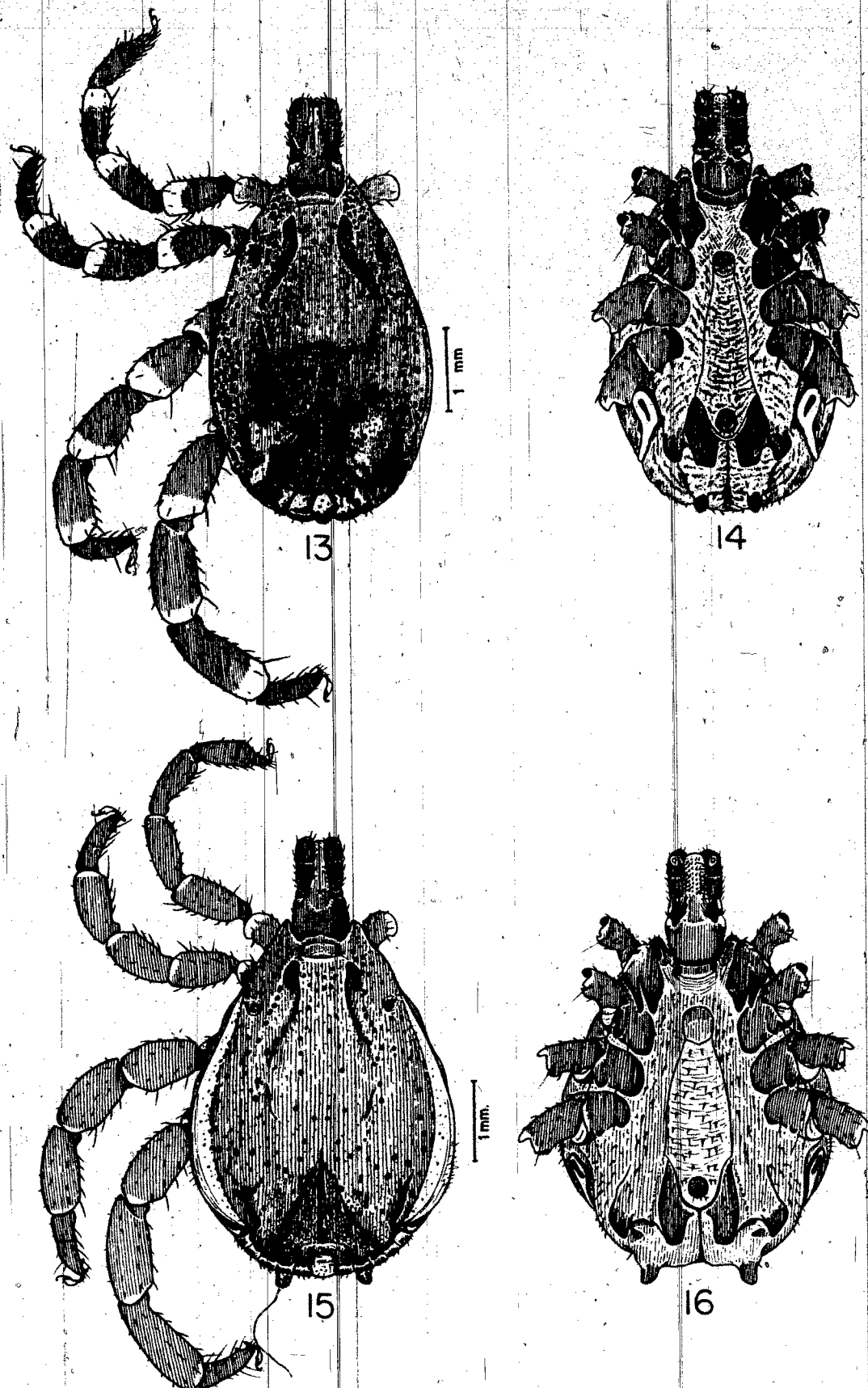
Inasmuch as it has been definitely established by Kratz (1940) and Feldman-Muhsam (1954) that the type specimen of *H. anatolicum* is lost, a neotype male of *H. anatolicum anatolicum* Koch, 1844, bearing the following data, "cattle, abattoir, Iskenderun, Turkey, 12 August 1954, H. Hoogstraal and M. N. Kaiser, collectors," has been selected and deposited in the United States National Museum together with a female bearing the same data. In addition, two males and one female bearing the same data are deposited in the following collections: Veterinary Faculty of Ankara University, Rocky Mountain Laboratory, Chicago Natural History Museum, American Museum of Natural History, Department of Zoology of University of Maryland, British Museum (Natural History), Institute of Malariology and Parasitology (Moscow), Academy of Science (Leningrad), Museum National d'Histoire Naturelle (Paris), Centro de Zoologia (Lisbon), Institute of Parasitology (University of Rome), Institutes Pasteur in Tunis, Alger, and Casablanca, Entomological Society of Egypt, East African Veterinary Research Organization (Muguga), Division of Veterinary Services (Onderstepoort), the writers, and others.

The neotype male is described above, under Identification, together with others in the same lot. The neotype male scutum measures 3.50 mm. in length and 2.00 mm. in width; the scutum of its associated female measures 1.90 mm. in length and 1.71 mm. in width.

In accordance with the International Rules of Zoological Nomenclature, approval for selection of this neotype has been obtained from the following ixodid specialists: Drs. C. B. Philip and G. M. Kohls (Hamilton), J. Tendeiro (Lisbon), O. Starkoff (Rome), and G. Theiler (Onderstepoort). Professor Serdyukova, however, declined comment except to refer to recent Soviet opinion [i.e. Pervomaisky (1954)]. A copy of the manuscript was sent to Dr. Francis Hemming, Secretary of the International Commission of Zoological Nomenclature, seven months before being submitted for publication.

## SUBSPECIFIC INTERGRADATION

As noted above, we have studied well over 10,000 specimens of *H. a. anatolicum* from 26 countries and territories ranging from the Atlantic coast of North Africa to India. In many of these areas, all available specimens are morphologically strictly representative of their own subspecies and can be identified with certainty. In certain areas, a small to moderate degree of random overlap occurs between populations of the two subspecies. In Egypt, this hybridization amounts to somewhat less than 20 percent in populations on the Mediterranean littoral, 5 to 10 percent in the Lower Nile Valley and Delta, and none in



FIGS. 13-14.—*H. anatolicum excavatum* (sensu Pomerantzev). ♂, dorsal and ventral, heavily punctate, not engorged (subanal shields normal), Egypt.

FIGS. 15-16.—*H. anatolicum excavatum* (sensu Pomerantzev). ♂, dorsal and ventral, punctate, not normally engorged (subanal shields displaced), Egypt.

Upper Egypt. In Turkey, it is approximately 2 percent throughout the Anatolian highlands to the eastern boundaries of the country but reaches approximately 5 percent in the lowlands around Iskenderun, near Syria. In Libya, it is somewhat less than 20 percent in our numerous samples, mostly from the Mediterranean littoral. In other areas from which we have large representative collections, i.e., Sudan, French Somaliland, Yemen, eastern Saudi Arabia, and Iraq, and in others from which our samples are smaller, no overlap has been observed.

Intergrading males are of intermediate size, from approximately 3.65 to 4.10 mm. in scutal length, the posteromedian and paramedian grooves are more pronounced than in the larger subspecies (i.e., *anatolicum*), the legs are reddish, and the scutal color is variable between the two subspecies. Females are also intermediate in size, their scutum measuring from approximately 1.85 to 2.15 mm. in length, and their legs being variable in color.

### *Hyalomma (Hyalomma) anatolicum excavatum* Koch

#### The Large Anatolian Hyalomma

(Figures 13-19, 24)

*Hyalomma excavatum* Koch, 1844, p. 222, short description of ♂ from Egypt. Kratz (1940) reported the type specimen(?) to be in the Zoological Museum of Berlin and Feldman-Muhsam (1954) reported a single type male in the Schulze collection. Where this specimen is presently deposited is not certain.

*H. excavatum* Koch; Koch, 1847, pp. 14, 45-46, Plate VI, Fig. 22, ♂ redescribed and illustrated.

*H. anatolicum* Koch; Schulze and Schlottke, 1930, pp. 36 and 44, keys to both sexes.

*H. anatolicum zavattarii* n. subsp., Tonelli-Rondelli, 1935, pp. 240-242, fig. 1, description and illustration of ♂ from Murzuch, Fezzan, Libya. We consider this to be a synonym of *H. anatolicum excavatum*.

*H. anatolicum anatolicum* Koch; Kratz, 1940, pp. 529-531, figs. 12-14; descriptions and illustrations of both sexes from material in Schulze collection.

*H. anatolicum excavatum* Koch; Pomerantzev, 1946, pp. 24 and 27, new combination, key to both sexes.

*H. excavatum* Koch; Delpy, 1949B, pp. 475, 485, 486, new synonymy; no reference to type material.

*H. anatolicum excavatum* Koch; Pomerantzev, 1950, p. 214, short comparative description of ♂; synonymy of *H. turkmeniense* Olenov, 1932 (sic; should be 1931) under this name.

*H. excavatum* Koch; Feldman-Muhsam, 1954, pp. 155-159, description and illustration of type specimen, synoptic list; Schulze collection specimens (of both subspecies) considered to be "within range of variation of *H. excavatum*."

*H. excavatum* Koch; Tendeiro, 1956, pp. 386-389, descriptions and illustrations of both sexes, separation of *H. lusitanicum*; synoptic list.

*H. excavatum* Koch and *H. sp. no. 2* near *excavatum*; Hoogstraal, 1956, pp. 435-451, 878-879, 884-887.

*H. anatolicum* Koch; Serdyukova, 1956, pp. 79-84; key to species only.

*H. excavatum* Koch; Anastos, 1957, p. 149, literature review including both subspecies.

A very few non-Soviet students referred to the present subspecies as *H. anatolicum* following the work of Schulze and Schlottke (1930), which amounted merely to a key to species. Material in the Schulze collection was elucidated by Kratz (1940, pp. 529-531) who redescribed both sexes and illustrated (figures 1, 12-14) the *H. anatolicum* specimens in this collection from southern Europe, the Near East, Middle Asia, Northwest Africa, and East Africa (i.e. Kenya). Kratz very likely confused several specimens of other species in the material he described. Tonelli-Rondelli (1932B, p. 373) reported a specimen from Libya and also described (1935) the synonymous subspecies *zavattarii* from Somalia. Bodenheimer (1937, p. 244) noted the presence of this form in Palestine. Various authors listed by Hoogstraal (1956, p. 438) have reported *H. anatolicum* from Kenya. [To our surprise we found an accurately determined specimen labelled Kabete, Kenya, in the Schulze collection. This Kenya sample was probably from a temporary population resulting from an adventitious introduction.] All of these 1930-40 workers were students of or in correspondence with Professor Schulze.

#### MATERIAL EXAMINED

Total.—Approximately 6,000 specimens collected in nature and numerous others reared in the laboratory. Owing to the negligible amount of previous information concerning this subspecies, all available locality data and host and month of collection data are presented below. Because of its historical importance, material in the Schulze collection is listed separately.

*Schulze collection*.—The following specimens, now in the Schulze collection in the Rocky Mountain Laboratory, bear Schulze's labels of *H. anatolicum* and are typical of *H. anatolicum excavatum*. (Areas in parentheses are our additions; other words in parentheses are illegible). 15 ♂♂ [Usak, Anat(olia) (Turkey) Heint]. 22 ♂♂, 1 ♀ [Rind, Usak, Anat(olia) (Turkey) Steiner leg.]. 10 ♂♂, 13 ♀♀ [*Bos taurus*, Ins. Skyros (Skiros Island, Greece), leg. Stephanides, Apr. 10, 1936]. 4 ♀♀ [*Bos taurus*, Ins. Skyros (Skiros Island, Greece), Aug. 10, 1935]. 3 ♂♂, 3 ♀♀ [*Ovis aries*, Ins. Skyros (Skiros Island, Greece), Stephanidis leg., Aug. 10, 1935]. 1 ♂, 1 ♀ [15 *Ovis aries*, Ins. Thassos (Thasos Island, Greece), leg. Kanellis, Aug. 6, 1935]. 5 ♂♂ [Pferd. Maz. (? Macedonia, Greece)]. 2 ♂♂, 1 ♀ [Maz. (? Macedonia, Greece)]. 1 ♂ [Cerniste, Maz. (? Macedonia, Greece). *Nuttallia equi* 18.6.17]. 1 ♂ [Zecke von Kamel, Kairo (Egypt), Dr. med. E. Bannworth leg., vend. 1.IX.1913]. 4 ♀♀ [Pferd. Kazakstan, Stadt. Turkestan (Russia), N. Olenov leg. 2.VI.1929]. 1 ♂ [37. Kabete, Kenya]. 1 ♂, 5 ♀♀ [Rio d'Oro (Spanish Sahara) P. Gratz L.V. (? Mendas antilope)]. 1 ♀ [Rio d'Oro (Spanish Sahara), Spasr G.V.I.N. G.2250/26)]. 14 ♂♂ [Rind,



Novo Selo (? Nuvo Sels or Nuvs Lels) 15/10]. 1 ♀ [Perniga (? Perugia)]. 1 ♂ [Hudova, Mared (? Hutova, Maret), Fehringer].

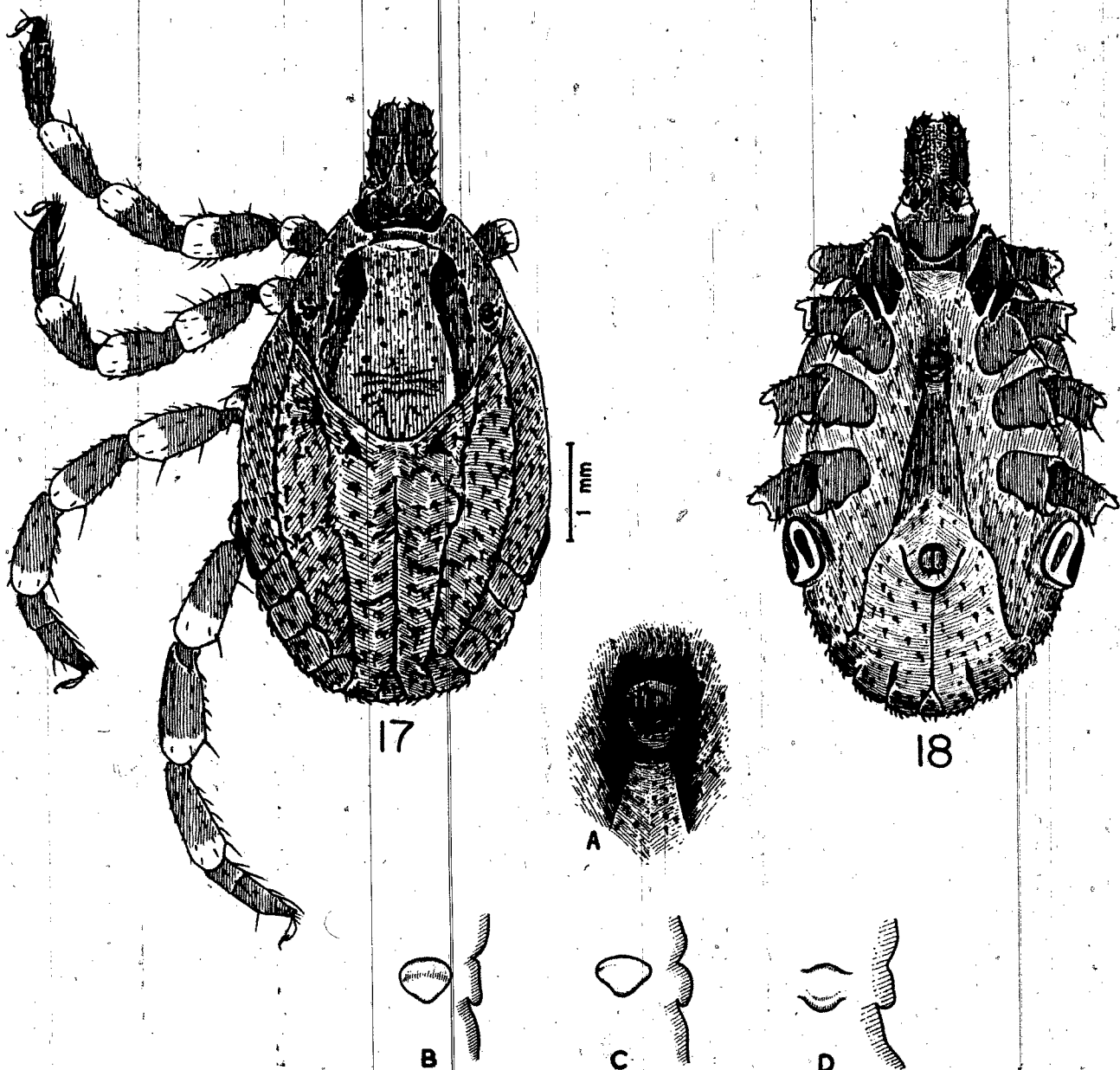
Also in the Schulze collection are the following specimens, labelled as *H. tunesiicum* subsp., which are typical of *H. a. anatolicum* [for further details see Hoogstraal and Kaiser, 1958b.] 2 ♂♂, dog and sheep, Agordat, Eritrea, spring, 1931 (cotypes of synonymous *H. tunesiicum ganorai* Tonelli-Rondelli). 1 ♂, Arak River, Transcaucasia, 1 January 1906.

#### KNOWN DISTRIBUTION

SPANISH SAHARA. Schulze collection, no locality. MOROCCO. Mogador (BMNH). ALGERIA. Specimens in Tendeiro collection from Institut Pasteur d'Algérie (personal communication).

TUNISIA. Tunis (Schulze collection; probably type of *H. tunesiicum* Sc. & Sc.). LIBYA (CYRENAICA). 3 to 5 kilometers west of El Agheila; Ghemines, Gardinia, and Beneina (all NAMRU3). (TRIPOLITANIA.) Specimens in Tendeiro collection (personal communication). See also records from Libyan camels in Egypt.

EGYPT. *Western Desert Governorate*: Siwa Oasis, Salum, Bir Bosslanga near Salum, Mersa Matruh, El Alamein, El Hammam, Burg El Arab, Bahig, El Amiriya, Wadi Natroun. *Cairo Governorate*: Cairo (transient animals and others in abattoir). *Red Sea Governorate*: near Cairo, near Zagazig, Ain Sukhna, Wadi Bikhait, and St. Anthony's Monastery (Wadi Araba). *Southern Desert Governorate*: Bir Abraq. *Sinai Governorate*: Feiran Oasis, Wadi Feiran, St. Catherine's Monastery



FIGS. 17-18.—*H. anatolicum excavatum* (sensu Pomerantzev). ♀, dorsal and ventral, Egypt.

(5,000 feet elevation), El Arish, Kosaima. *Introduced into Egypt*: Cairo abattoir (numerous ♂♂ on camels and cattle said to originate in the Sudan, and on cattle said to originate in "East Africa," possibly Somaliland or Ethiopia). Alexandria Quarantine Station (♂♂ on camels from Libya). Salum Frontier Station and El Hammam market (numerous ♂♂ and ♀♀ on camels from Libya). See also Schulze collection data above. Note absence in Nile Valley and Delta.

SUDAN. Kassala, Kassala. ETHIOPIA (ERITREA). Agordat (Schulze collection, as *H. tunesiacum ganqrai* Tonelli-Rondelli). FRENCH SOMALILAND. Plaine de Haule, Ali Sabiet, and Djibouti (HH). KENYA. Kabete (Schulze collection, probably from a nonestablished, adventitiously introduced population).

YEMEN. Ta'izz (HH). PALESTINE. Jaffa and Gaza (BMNH and NAMRU3).

CRETE. (Schulze collection, "probably *H. tunesiacum* Sc. & Sc."—note by Kohls.) GREECE. Macedonia and Skyros (Skiros) and Thasos (Thassos) Islands (Schulze collection).

TURKEY. Usak (Kutahya) (Schulze collection). Istanbul and Ankara abattoirs, Kara Kopru (Urfa), and Iskenderun (Hatay) (HH & MNK). Ayvalik, Kurktoy, Nesbiye, Kadirli, and Asayiciyanli (Ceyhan), Gocer (Maras) (NAMRU3). Kirklareli (Kirklareli), Bursa (Bursa), Manyas (Balikesir), Salihli (Manisa), Nazilli (Aydin), Bodrum (Mugla), Saraykoy and Acipayam (Denizli), Ladik (Samsun), Niksar (Tokat), Amasya (Amasya), Tarsus (Icel), Hassa, Reyhanli, and Dortyol (Hatay), Birecik (Urfa), Kulp (Diyarbakir) (RML). In Turkey this form ranges from the Greek and Bulgarian frontiers at least to longitude 40°E. and is common locally in the lowlands and foothills near the Black and Mediterranean Seas but rare on the high Anatolian steppes and in the mountains of the old Kurdistan area.

U.S.S.R. Kazakh S.S.R. (Schulze collection). Specimens in HH collection lack locality labels. [According to Pomerantzev (1950, p. 214) this subspecies occurs in Turkmen S.S.R., southern Kazakh S.S.R., and Tazhik S.S.R. IRAN. Pomerantzev (*loc. cit.*) states that this form also occurs in Iran].

#### HOSTS OF ADULTS AND MONTH OF COLLECTION

SPANISH SAHARA. Antelope: 1 ♂, 5 ♀♀. MOROCCO. Cattle: 11 ♂♂, 7 ♀♀. LIBYA. Camels: 25 ♂♂, 12 ♀♀ (October). Goats: 1 ♂, 3 ♀♀ (April), 4 ♂♂, 2 ♀♀ (October). Cattle: 4 ♂♂, 4 ♀♀ (November). Sheep: 1 ♂, 4 ♀♀ (November). On ground: 2 ♂♂ (October).

EGYPT. Man: 1 ♂ (March). Camels: 2 ♂♂ (January), 93 ♂♂, 10 ♀♀ (February), 49 ♂♂, 5 ♀♀ (March), 21 ♂♂, 11 ♀♀ (May), 11 ♂♂, 6 ♀♀ (June), 1 ♂ (July), 87 ♂♂, 22 ♀♀ (October), 8 ♂♂, 1 ♀ (December) (see also market camels below). Cattle: 24 ♂♂, 11 ♀♀ (January), 1 ♂ (September). Donkeys: 52 ♂♂,

13 ♀♀ (March). Sheep: 8 ♂♂, 3 ♀♀ (December), 32 ♂♂, 15 ♀♀ (January), 19 ♂♂, 11 ♀♀ (February), 1 ♂, 2 ♀♀ (March), 2 ♂♂, 3 ♀♀ (April), 16 ♂♂, 4 ♀♀ (August), 35 ♂♂, 10 ♀♀ (October). Goats: 4 ♂♂ (February), 7 ♂♂ (May). On ground: 1 ♀ (October). On ground in camel yard: 4 ♂♂, 7 ♀♀ (October), 68 ♀♀ (February). On ground, desert: 1 ♀ (October). On abattoir animals from foreign countries: 4 ♂♂ (January), 39 ♂♂ (February), 1 ♂, 5 ♀♀ (October), 39 ♂♂ (November). On Libyan camels at Salum Frontier Station: 2 ♂♂, 1 ♀ (October). On Libyan camels (10 each month) at El Hammam market: 69 ♂♂, 220 ♀♀ (December), 235 ♂♂, 285 ♀♀ (January), 237 ♂♂, 197 ♀♀ (February), 145 ♂♂, 412 ♀♀ (March), 110 ♂♂, 797 ♀♀ (April), 169 ♂♂, 494 ♀♀ (May) (no June collections), 168 ♂♂, 501 ♀♀ (July), 140 ♂♂, 372 ♀♀ (August).

SUDAN. Camel: 1 ♂, 4 ♀♀ (May). ERITREA. Dog and sheep: 2 ♂♂ (spring). FRENCH SOMALILAND. Camels: 4 ♂♂, 2 ♀♀ (July). Cattle: 1 ♂ (July). Sheep: 2 ♂♂ (July). Goats: 1 ♂ (July).

YEMEN. Camels: 10 ♂♂, 1 ♀ (February). Cattle: 9 ♂♂, 5 ♀♀ (February). PALESTINE. Cow: 1 ♂ (June). Camel: 8 ♂♂, 1 ♀ (July).

CRETE. No Host: 1 ♂ (June). GREECE. Cattle: 10 ♂♂, 13 ♀♀ (April), 4 ♀♀ (August). Horse: 5 ♂♂ (no month). Sheep: 4 ♂♂, 4 ♀♀ (August).

TURKEY. Cattle: 50 ♂♂, 17 ♀♀ (no month), 6 ♂♂, 17 ♀♀ (June), 2 ♂♂, 14 ♀♀ (July), 41 ♂♂, 7 ♀♀ (August), 11 ♂♂ (September). Sheep: 1 ♂ (September). Horses: 8 ♂♂, 18 ♀♀. Donkeys: 3 ♂♂, 1 ♀. Mule: 2 ♂♂. Goats: 16 ♂♂, 11 ♀♀. Buffaloes: 4 ♂♂, 4 ♀♀. Camels: 6 ♂♂.

RUSSIA. Horse (Schulze collection). No hosts or seasonal data are reported by Pomerantzev (1950) or recorded on labels of Russian material in HH collection.

In summary, camels and cattle appear to be usually the most consistent and heavily infested hosts. Sheep, goats, and horses may be somewhat less important hosts, and domestic buffaloes, donkeys, mules, man, dogs, and antelopes serve as occasional hosts. The rate of infestation varies with locality and season and more careful studies on this subject are obviously required.

#### HOSTS OF NYMPHS (EGYPT)

The following are the data for adults of *H. anatolicum excavatum* that we have reared from nymphs in Egypt. We are unaware of any other published data for the immature stages of this form. In the paragraphs below, the hosts' scientific and common names are listed together with the locality and time of collecting. In the field it was not always possible to observe the exact date that nymphs dropped from the host or molted to adults.

*Paraechinus d. dorsalis* (Anderson and de Winton, 1901), Arabian Paraechine Hedgehog. Wadi Feiran, Sinai, adults reared from nymphs collected on 21 May 1953 and from St. Catherine's Monastery on 24 and 26 May 1958.

*Hemiechinus auritus libycus* (Ehrenberg, 1833), Libyan Long-eared Hedgehog, Burg El Arab, Western Desert; nymphs disengaged from host on 22 October, molted to adults on 17 November; other newly molted, unengorged adults from burrows of this form of hedgehog 70 miles east of Mersa Matruh, Western Desert, 22 September.

*Hemiechinus auritus metwalli* Setzer, 1957, Nile Delta Long-eared Hedgehog. Various localities in Beheira Province, adults reared from nymphs from hosts taken in May, September, and November.

*Lepus capensis rothschildi* de Winton, 1902, Rothschild's Hare. Seacoast 4 miles east of Libyan frontier, nymphs collected in October 1953.

*Jaculus j. jaculus* (Linnaeus, 1758), Common Lesser Jerboa. 12 miles east of El Amiriya, Mariut, Western Desert, nymph dropped 29 October 1954, molted on 30 November.

*Acomys russatus* (Wagner, 1840), Golden Spiny Mouse. 8 adult ticks reared from nymphs at St. Catherine's Monastery (5,000 feet altitude), Sinai, November 1952.

*Gerbillus (G.) gerbillus gerbillus* Olivier, 1801, Egyptian Lesser Gerbil. 5 adult ticks reared from nymphs from hosts from the desert fringe west of Cairo.

*Meriones c. crassus* Sundevall, 1842, Eastern Desert Jird. Midway between Cairo and Suez, adults reared from nymphs taken 12 April 1953, 24 October 1957, and 23 January 1958.

*Meriones crassus pallidus* Bonhote, 1912, Pale Jird. Female from nymph, Bir Abra, South-eastern Desert, February 1954.

*Psammomys o. obesus* Cretzschmar, 1828, Fat Sand-rat. Several unengorged, newly molted adults from burrows in the Eastern Desert 29 kilometers east of Cairo (17 December 1954), at Hafs, Damanhur, Beheira and in the Western Desert at Mersa Matruh (9 November 1953, 23 September 1954 and 21 September 1957); in addition 15 adults were reared from nymphs that dropped from fat sand-rats at several of the localities noted above.

"Rodent burrows." Several unengorged, newly molted adults from Wadi Nasuri, Eastern Desert, and Libyan Plateau overlooking Salum, Western Desert (October 1953).

#### LIFE CYCLE

Rearing experiments (with the technical assistance of Sobhy Gaber) indicate that *H. anatolicum excavatum* may undergo either a two-host or three-host type of life cycle. An engorged female removed from a camel at Abu Rawash, Giza, Egypt, on 23 May 1957, and held at Cairo summer room temperature, commenced oviposition on

1 June; these eggs hatched on 27 June. On 31 July, 292 larvae from this batch were placed on the ear of a rabbit. On 3 August, 151 of these larvae detached and molted to nymphs on 8 August; they were then preserved for morphological study. However, 141 larvae remained on the host and molted to nymphs. After feeding, 43 of these nymphs detached on 12 August and molted to 22 males and 21 females on 26 August; 49 detached on 13 August and molted to 36 males and 13 females on 28 August; 31 detached on 15 August and molted to 12 males and 19 females on 29 August; 18 detached on 16 August and molted to 6 males and 12 females on 30 August.

In summary, 27 days are required for hatching of eggs held in humidified tubes at Cairo summer room temperature. Of 292 larvae secured from a single egg batch, 151 detached from the rabbit host after 4 days of feeding and molted to nymphs 5 days later (three-host type of life cycle); they were then preserved. A slightly smaller number of larvae, 141, underwent a two-host type of life cycle, remaining on the same host, feeding, molting to nymphs, feeding again, and then detaching from 13 to 17 days after having been placed on the host as unfed larvae. These individuals molted to 76 males and 65 females 14 or 15 days after having detached as engorged nymphs. Assuming the prefeeding period of newly hatched larvae to be 4 days, 58 to 63 days are necessary to complete the two-host cycle from oviposition to appearance of adults under conditions described above. Life cycle studies of subsequent generations are presently underway.

During the winter, spring, and summer of 1958, after the main body of this manuscript was completed, we have been rearing the progeny of individual females of both subspecies of *H. anatolicum* (and of *H. lusitanicum*) on a variety of hosts. The results, even in the  $F_2$  generation, contain no evidence to suggest that these are not two distinct biological and taxonomic entities. Indeed, the individual morphological characteristics of the immature stages have proved to be even more distinct than we had thought might be possible. The results of this study will be presented in a separate report in the present series.

#### IDENTIFICATION

The description of *H.* sp. no. 2 near *excavatum* (Hoogstraal, 1956, pp. 886-887) is herein expanded to provide more precise definition of this subspecies.

*Males*.—Medium-size to large ticks usually measuring from 4.00 to 5.12 mm. (or larger) in length and from 2.55 to 3.55 mm. (or more) in width; average specimen 4.50 mm. in length and 2.95 mm. in width. Individuals and limited populations ranging somewhat smaller than these dimensions can usually be readily distinguished from the related subspecies by morphological

criteria. Color is shiny dark brown or reddish brown. The caudal depression has numerous, often contiguous, small punctations, large punctations are usually absent in this depression but may be present in very robust, comparatively heavily punctate individuals. The shallow posteromedian groove is separated from the white or pale parma by a slightly elevated pons formed by the anterior extension and sometimes fusion of the paraparmal festoons; the caudal depression is bounded laterally by distinctly

heavily chitinized, their external margin is usually rectangular; their outer margin is convex, usually strongly so. The subanal shields are larger and more heavily chitinized than in the subspecies *anatolicum* and none have been observed to be rudimentary or absent. The light or yellowish brown legs are sometimes faintly striped and usually marbled when dry.

*Female*.—The scutum measures from 2.09 mm. to 2.61 mm. in length (or possibly more) and from 2.04 mm. to 2.42 mm. (or more) in width; average specimens are 2.33 mm. in length and 2.23 mm. in width. The scutum is darker, somewhat more heavily punctate, and with large punctations deeper than those of the subspecies *anatolicum*. The bulging genital apron is typically widely triangular in outline; it may also be circular or widely triangular. The legs are light brown, usually with faint reddish brown rings, and usually marbled when dry.

*The type specimen*.—Koch's type specimen was noted by Kratz (1940, p. 531) to be "a male from Egypt with a large depressed caudal field and incomplete pons over the white parma." It was described by Feldman-Muhsam (1954, p. 156) as follows: "The length of the scutum is ca. 4 mm., the width ca. 2.6 mm. The cervical grooves are long and superficial. The lateral grooves are very short. The parma is white. The third, fourth, and fifth festoons are fused. At the fused festoons starts a longitudinal elevation which extends anteriorly to the hinder part of the scutum. Between these elevations, the whole caudal field is strongly depressed. The depressed field is finely punctated. The outer margin of the anal plates is strongly convex laterally. The inner margin of the anal plates form an acute extension behind the anus." Illustrations after Feldman-Muhsam are reproduced herein (figures 19A, B).

Feldman-Muhsam's description and illustrations tally exactly with the critical diagnostic characters for identification of typical specimens of the subspecies *excavatum*. These features are length and width of the scutum, anterior fusion of paraparmal festoons, obscurity of posteromedian groove, absence of large punctations in caudal depression, elevated ridges beside caudal depression, length of cervical grooves, large size of subanal shields, and robustness and convex external margins of adanal shields.

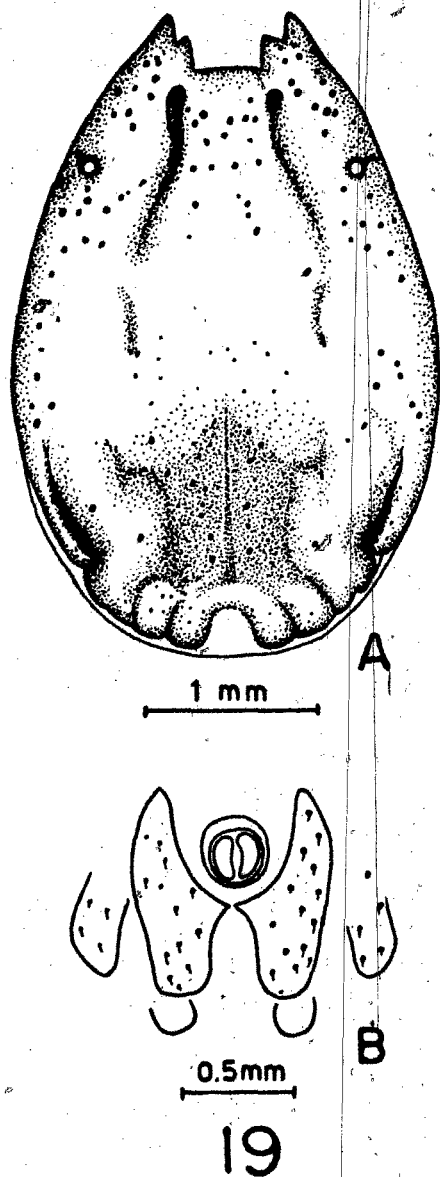


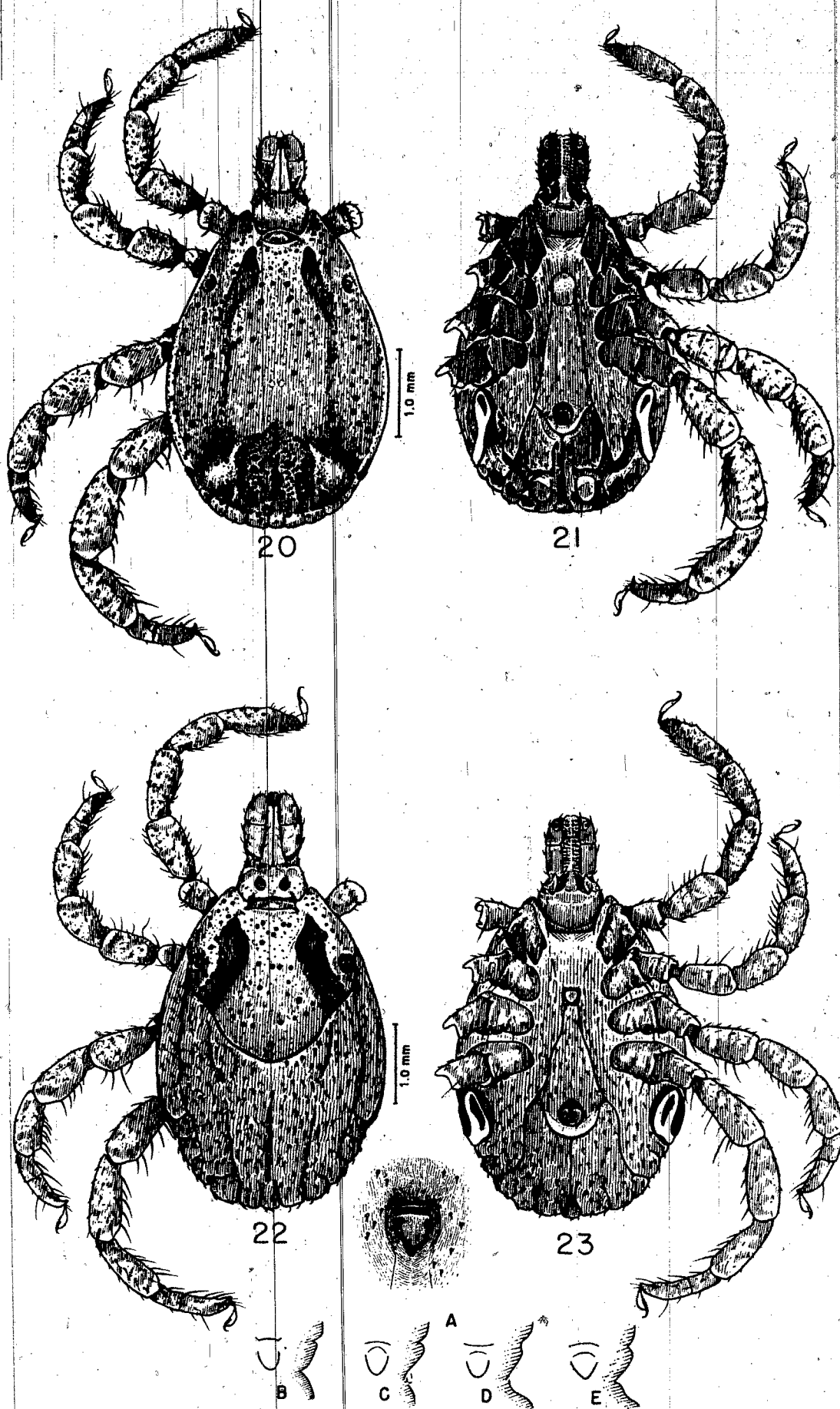
FIG. 19.—Type specimen of *H. excavatum* Koch, 1844 (After Feldman-Muhsam, 1954). A. Scutum. B. Posterior ventral surface.

elevated ridges. The shallow cervical grooves extend at least to or beyond the anterior third of the scutum. Large punctations in the central field are deeper than in the subspecies *anatolicum* but the scutal surface appears smoother than in that subspecies. The adanal shields are more

#### COMPARISON OF *H. anatolicum excavatum* AND *H. franchinii*

Males of the apparently uncommon and geographically limited species *H. franchinii* Tonelli-Rondelli 1932(A), morphologically are superficially fairly similar to those of *H. anatolicum excavatum*, but their females are readily distinguishable and biological characteristics of each form are unique (see Hoogstraal and Kaiser,





FIGS. 20-23.—*H. lusitanicum* ♂ and ♀, dorsal and ventral, Portugal (Specimens presented by Dr. J. Tendeiro).

1958A, B). In an artificial key to males, these two forms might appear to be closely related; we believe, tentatively, that they are not closely related phylogenetically. The comparative characters below should easily differentiate these two forms.

*H. franchinii**H. anatolicum excavatum*

## MALES

Scutum round-oval average, 4.18 x 2.74 mm.	comparatively elongate-oval, 4.50 x 2.95 mm.
Cervical field smooth with few large punctations	less smooth, more punctate
Cervical grooves smooth, short; confined to anterior third of scutum	deeper, longer; usually extending beyond anterior third of scutum
Parma usually elongately triangular	broadly triangular or subrectangular
Paraparmal festoons not extending as pons	usually as pons
Second pair of festoons long	short, truncated by paramedian grooves
Caudal field triangular, with straight lateral margins	lateral margins irregularly rounded
Spiracular plates with long, thin, tapering tail	tail moderately wide, slightly curved apically
Adanal shields with slight posteromedian indentation	lacking posteromedian indentation
Subanal shields small or frail	always strong

## FEMALES

Genital apron short, covering basal half of aperture	long, bulging over entire length of aperture
Scutum with broadly rounded posterior margin	more elongate and narrowly rounded posteriorly
Cervical field glossy, with few large punctations	more punctate
Cervical grooves shallow, smooth, faint posteriorly	deep, more punctate laterally, reach posterior margin

## IMMATURE STAGE (BIOLOGY)

Usually infest reptiles	usually infest small mammals
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*Hyalomma (Hyalomma) lusitanicum* KochThe Lusitanian *Hyalomma*

(Figures 20-23, 26)

*Hyalomma lusitanicum* Koch, 1844, p. 222, short descriptions of ♂ and ♀ from Portugal; type material not subsequently reported as seen and obviously, by this time, destroyed or mislabelled.

*H. lusitanicum* Koch; Koch, 1847, pp. 14, 36-38, Plate 3, Figs. 10 and 11. Both sexes redescribed and illustrated.

*H. aegyptium lusitanicum* Koch; Neumann, 1911, p. 51, new synonymy.

*H. lusitanicum lusitanicum* Koch; Kratz, 1940, pp. 527-528, fig. 8, diagnosis of both sexes, in part confused with other species from Algeria; no type specimen mentioned.

*H. excavatum* Koch; Delpy, 1949B, pp. 476 and 487, new synonymy, type specimen not seen.

*H. excavatum* Koch; Feldman-Muhsam, 1954, p. 159, synonymy; type specimen stated to be lost.

*H. lusitanicum* Koch; Tendeiro, 1956, pp. 397-406, figs. 21-22, redescription of both sexes, illustrations of ♂ dorsal surface and ♀ genital aperture, includes extensive bibliography and history of synonymy, geographic range limited to Portugal and Spain.

*H. lusitanicum* Koch; Tendeiro (in press), selection and deposition of neotype from Portugal, in British Museum (Natural History).

## DISTRIBUTION AND HOSTS

**Material examined.**—Total 75 ♂♂, 52 ♀♀; others from Morocco are being reared in our laboratories. PORTUGAL. 19 ♂♂, 6 ♀♀, from cattle, sheep, and *Dama dama* (Linnaeus) (fallow deer), Portel and Alentejo; HH collection, gift of Dr. J. Tendeiro. CANARY ISLANDS. 3 ♂♂, 11 ♀♀, from cattle, G. W. Perez leg. 1916, Nuttall lot 3226 in BM(NH), 1 ♂, 2 ♀♀ in HH collection. MOROCCO. 31 ♂♂, 31 ♀♀, from European rabbits, *Oryctolagus cuniculus* (L.), Nefik Forest near Casablanca, HH collection, gift of Dr. G. Blanc (see Blanc and Bruneau, 1956, as *H. excavatum*). ITALY. 21 ♂♂, 1 ♀, from cattle, sheep, and goats, Augusta (Siracusa), Catafani, and Agrigento, HH collection, gift of Professor O. Starkoff. FRANCE. 1 ♀, from man, Le Trayas.

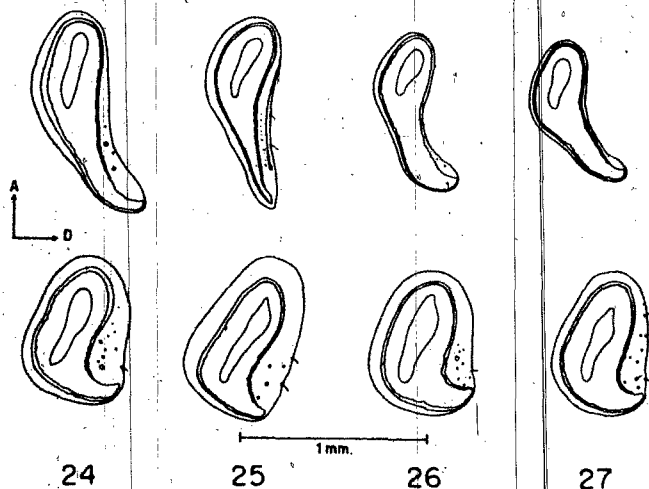
ITALY. *H. lusitanicum* is replaced by *H. a. anatolicum* in Sicily, Puglia, and Calabria, e.g. Sicily and southern Provinces of the mainland (Professor O. Starkoff, personal communication). SPAIN. Reported by Tendeiro (1956, p. 398), from *Cervus elaphus* subsp. (red deer); no locality. CANARY ISLANDS. Specimens from pigs have been received by Dr. J. Tendeiro (personal communication).

**Summary.**—The known range of *H. lusitanicum* is Italy (except Sicily, and southern Provinces of the mainland), southern France, Spain, Portugal, Morocco, and Canary Islands. Known hosts are cattle, sheep, goats, pigs, fallow deer, red deer, and European rabbits.

## IDENTIFICATION

**Male.**—Small to medium size, reddish brown ticks with scutum averaging 3.70 mm. in length and 2.60 mm. in width (range 3.25 to 4.05 mm. in length and 2.40 to 2.80 mm. in width). Lateral grooves are extremely short or absent. The central field of the scutum has few large and scattered fine punctations that become more numerous and heavy laterally and in the cervical and scapular areas. Cervical grooves originate as deep pits and extend as smooth furrows to the scutal midlength. Posteromedian groove is faint and either does or does not reach the median festoon; paramedian grooves are short and indistinct, all three being more or less obscured by numerous punctations and sometimes rugosity of caudal depression. Festoons consist of one median and two other pairs; laterally festoons are fused and continuous with the raised ridge bordering the caudal depression. A unique, dirty white marbling (in preserved specimens) occurs in the scapular areas, between the cervical grooves, and may also be found on the basis capituli and ridges bordering the caudal depres-

sion. A parma is absent in all specimens. However, in single specimens from the Canaries and Italy it is possibly very faintly developed and Dr. Tendeiro (personal communication) has also recently received specimens from the Canaries with a parma questionably present. The spiracle has a thick, long tail. The adanal shields are robust, fairly short, rectangular, and mostly indented in the mid-posterior margin. The fairly large subanal shields lie directly posterior of them and are usually rounded posteriorly. The reddish brown legs are usually conspicuously and extensively marbled when dry.



FIGS. 24-27.—Spiracular plates of *H. anatolicum excavatum* (24), *H. franchinii* (25), *H. lusitanicum* (26), and *H. a. anatolicum* (27). Drawn from ticks, not from mounts. ♂♂, upper row. ♀♀, lower row.

**Females.**—The comparatively wide, short scutum in our specimens measures approximately 2.20 mm. in length and 2.00 in width; its reddish brown to dark brown color is extensively marbled when dry, as are the basis capituli and dorsal surfaces of the palpi. Punctations are comparable to those of the male. Cervical pits are very deep. Cervical grooves are deep, broad, extending to the posterolateral margin of the scutum, and usually with some large punctations and lateral rugosity. The genital apron, more or less widely shield like in outline, does not bulge in profile (thereby definitely establishing this as a species differing from *H. anatolicum* subsp.) but is gradually depressed posteriorly. The reddish legs, as in the male, are extensively marbled.

**Original description.**—Koch's original description, translated, is as follows:

"12. *H. lusitanicum*—Scattered punctations, wine-red, a small, round edge white. Legs rust-red sprinkled with brown-red, the border of the segment bright light yellow, likewise brown-red sprinkled. Length  $1\frac{2}{3}$ ". Male."

"Just the same, the coarsely punctate thorax is ringed anteriorly in yellow; the wrinkled posterior area dark wine-red, on the sides dark yellowish. Length  $1\frac{3}{4}$ ". Female."

"Origin: Portugal."

From Koch's numerous references in the original description and in the 1847 redescription to contrasting coloration, and from the geographical origin of the material, there appears to be no doubt of the association of material today considered to be *H. lusitanicum* with that originally described under this name.

#### KEY TO *H. ANATOLICUM* GROUP

##### MALES

Lateral grooves absent or less than one third scutal length. Subanal shields situated directly posterior of adanal shields (except in greatly engorged individuals). Punctations few to moderately dense but never dense or regularly distributed over scutum, variable in size and depth. Cervical grooves extend for at least one-third length of scutum. Caudal area depressed between two more or less raised ridges; posteromedian groove distinct, narrow, confined to caudal depression. Small to moderately large ticks. . . . .

##### (GROUP CHARACTERISTICS)

1. Medium size ticks with lateral grooves absent or at most not even so long as caudal depression. Parma usually absent or indistinct. Scutum with numerous small punctations; large punctations of various depths usually more dense and deep laterally, on scapulae, and between cervical grooves; ridges beside caudal depression distinctly elevated; caudal area with numerous rather large, deep, contiguous punctations; posteromedian groove often containing punctations but usually distinct and bordered by two small ridges; paramedian grooves usually obscure. Adanal shields short, robust, rectangular. Spiracular plate with a thick, long tail. Leg segments often extensively marbled (when perfectly dry) dorsally and apically. Southwestern Europe, northwestern Africa

##### *H. lusitanicum*

Small to moderately large ticks with above combination of characters varying. Lateral grooves usually approximately one-fourth of scutal length. Parma usually present and distinct. Scutum only exceptionally as punctate as above, usually smooth with few widely scattered large punctations and faint small punctations; caudal area usually with comparatively few large punctations and more numerous small punctations. Spiracular plate with thin, long tail (*H. anatolicum*, 2 forms) . . . . . 2

2. Moderately large, tough, reddish brown to dark brown ticks, scutal length usually over 4.00 mm. Ridges beside caudal field distinctly elevated. Subanal shields heavily chitinated, never rudimentary. Legs light brown, marbled when dry.

##### *H. anatolicum excavatum*

Small, frail, pale ticks; scutal length up to 3.85 mm. pale to pale reddish brown. Ridges beside caudal field weakly elevated. Subanal shields weak, often rudimentary or absent. Legs yellowish or pale brown, never marbled when dry.

##### *H. a. anatolicum*

##### FEMALES

Genital aperture either oval (shieldlike) and gradually depressed posteriorly or rounded or triangular (knoblike), short and bulging posteriorly. Scutum usually somewhat longer than wide, posterior margin comparatively narrowly rounded. Cervical grooves deep, broad, reaching posterior margin of scutum. Scutal punctations as anteriorly in males. . . . . (GROUP CHARACTERISTICS)

1. Genital apron outline elongate, shieldlike; profile gradually depressed posteriorly. Cervical grooves broad, with some punctations and lateral rugosity. Scutal punctations as in male. . . . . *H. hesitanicum*  
 Genital apron small, outline short, triangular; profile knoblike, slightly bulging. Cervical grooves narrow, smooth, with few punctations. . . . . *H. anatolicum*, 2 forms) . . . . . 2
2. Scutum strongly chitinized, usually more than 2.00 mm. in length; color reddish brown to dark brown. Genital apron typically widely triangular; also may be circular or elongately triangular. Legs with faint reddish brown rings, usually marbled when dry. . . . . *H. anatolicum excavatum*  
 Scutum weakly chitinized, less than 2.00 mm. in length; color yellowish brown to brown. Genital apron circular or elongately triangular, widely triangular only when engorged. Legs very faintly striped with pale yellowish brown rings, never marbled. . . . . *H. a. anatolicum*

## DISCUSSION AND CONCLUSIONS

## TAXONOMY

*Hyalomma anatolicum* Koch, 1844 (sensu Schulze) refers to *H. anatolicum excavatum* of the Pomerantzev school of Soviet workers while *H. excavatum* Koch, 1844 (sensu Delpy), as consistently and widely used by non-Soviet workers for at least a decade, refers to *H. anatolicum anatolicum* of the Pomerantzev school. This fact, which we have long suspected from review of Soviet literature, is now confirmed by comparison of Russian-identified specimens with those in the Schulze and in other collections.

After this circumstance was determined, our second problem concerned a critical questioning of the validity of the Pomerantzev opinion that the species *anatolicum* is composed of two subspecies, *anatolicum* and *excavatum*. We had already reported (Hoogstraal, 1956) a number of atypical specimens of *H. excavatum* and described and illustrated a closely related form, readily discernible as a separate morphological and biological taxon, as *H. sp. number 2* near *excavatum*. Shortly after completion of the 1956 work, Mr. G. Kohls made available to us that part of the Schulze collection that we had not already seen. It immediately became evident from this material that Schulze's *anatolicum* was our *H. sp. number 2* near *excavatum*. Thereupon, we spent several months restudying our *Hyalomma* collections. We were also privileged to examine the tremendous *Hyalomma* collections from Turkey belonging to the Rocky Mountain Laboratory. During this period, practically every one of our previously perplexing atypical specimens of "*H. excavatum*" was easily absorbed under *H. anatolicum* (sensu Schulze). Further, collation of biological data showed usually distinct biological characteristics of *H. excavatum* (sensu Delpy) and *H. anatolicum* (sensu Schulze). It was then obvious, even though non-Soviet workers from Delpy (1949A, B) to date had synonymized *anatolicum* under *excavatum*, that the two were related but distinct subspecies.

Our third problem was to determine whether Russian or non-Russian workers were correct in referring to *excavatum* as the larger of the two subspecies. Fortunately, Kratz (1940) had described some of the critical characters of the type specimen of *excavatum* and Feldman-Muhsam (1954) had nicely described, illustrated, and measured this specimen. The details of the type specimen of *H. excavatum* presented by these workers tally exactly with all material referable to *H. anatolicum* (sensu Schulze); therefore it is obvious that non-Soviet workers had not only erroneously applied the name *excavatum* to the small subspecies, but had also incorrectly lumped the two forms [i.e. *excavatum* (sensu Delpy) and *anatolicum* (sensu Schulze)].

The fourth problem was what to do about the name *H. anatolicum* Koch owing to the loss of the type female and the sketchy original description, which is insufficient definitely to identify the species. Here, we were forced into an arbitrary decision, and selected a *neotype* from the same general area as the original specimen (i.e. eastern Turkey). In so doing, the bulk of significant published references to this species and its subspecies become taxonomically stabilized; these are in literature from the U.S.S.R., where *H. anatolicum* subspp. is widely spread and of considerable medical and veterinary importance. Pomerantzev was not only the only previous worker to interpret *H. excavatum* correctly and to recognize these two related subspecies, but he also discerned what Koch's *H. anatolicum* most probably was (herein arbitrarily established by a *neotype*).

A fifth, tangential, problem presented itself when studying variation in subanal shields and in other morphological characters of large series of *H. a. anatolicum* (sensu Pomerantzev). A certain number of abnormal individuals almost invariably develop when tremendous masses of this tick feed on a single animal, when the immature stages utilize exceptional hosts, or when the life cycle is spent entirely in a rigorous desert environment (Pomerantzev, 1950, p. 214; Hoogstraal, 1956, pp. 447-448, 520-523). These individual variants possess all the characters ascribed to the type specimen of *H. rhipicephaloides* Neumann, 1901, and to other material described under this name by Feldman-Muhsam (1957). We must, therefore, reiterate the common contention that *H. rhipicephaloides* Neumann, 1901, is a synonym of *H. a. anatolicum* Koch, 1844, and that the subgenus *Hyalommina* Schulze, 1919, erected for it, has no validity. Santos Dias (1956) independently arrived at the same conclusion and established the subgenus *Delpyiella* for the Indian species *H. hussaini* Sharif, 1928, which actually does lack subanal shields. [Kohls, to whom we sent a representative sample from the lot illustrated herein, replied "Specimens such as these would appear to remove



any doubt about the status of *H. rhipicephaloides*." Similar abnormalities in other species of *Hyalomma* have also been named indiscriminately.

After these data and conclusions were set down, the preliminary manuscript was submitted to a number of distinguished colleagues with special interest in African-Asiatic ticks or in problems of zoological nomenclature. Various suggestions made by them have been incorporated into the report. Professor Serdyukova replied by calling attention to the current Soviet opinion, expressed by Pervomaisky (1954). As a result, we delayed submitting this report for some eight months during which we intensified and expanded our rearing experiments with both subspecies and with *H. lusitanicum*. The results, which amply confirm our thesis, will be presented in a subsequent section of this series.

#### BIOLOGY

Data referring to seasonal activities and immature-stage host-predilections of the two subspecies of *H. anatolicum* in Egypt confirm the morphological findings and definitely establish each as a separate, biologically and morphologically distinct, form. The geographic range of each is somewhat different and the ecological situations in which each occurs may, in some instances, differ dramatically. Once these two subspecies are better understood, additional biological criteria undoubtedly will be revealed.

Both forms have a wide, almost equal, geographic range, but both are replaced by *H. lusitanicum* in southwestern Europe. In Russia, both forms occur in Turkmen S.S.R., southern Kazakh S.S.R., and Tadzhik S.S.R., but only *anatolicum* also ranges into Daghestan, southern and eastern Transcaucasia, and Uzbek S.S.R. (Pomerantzev, 1950). Significantly, the subspecies *excavatum* does not breed in the cultivated Nile Valley and Delta where the subspecies *anatolicum* is ubiquitous. Furthermore, representatives of the subspecies *excavatum* are totally absent in our extensive collections from eastern Saudi Arabia, Iraq, and India, where the subspecies *anatolicum* is well represented. Present evidence suggests that *excavatum* is rare or possibly absent on the high Anatolian steppes and in the mountains of Kurdistan in eastern Turkey; the subspecies *anatolicum* is common in these areas.

The geographic distribution of the previously poorly known *H. anatolicum excavatum* is now established as scattered localities in a belt from Spanish Sahara (Rio de Oro) on the Atlantic Coast of North America across North Africa to Palestine, southwards on both coasts of the Red Sea into Yemen (southwestern Arabia), and into the Sudan, Eritrea, and French Somaliland (with possibly a non-established population once having been introduced into the mountains of Kenya). Northwards and eastwards it occurs in Crete,

Greece, and associated islands, parts of Turkey, Turkmen S.S.R., southern Kazakh S.S.R., Tadzhik S.S.R., and Iran.

The geographic range of *H. a. anatolicum* is confirmed (as previously reported by Hoogstraal, 1956, for "*H. excavatum*", with the exception that it is replaced by *H. lusitanicum* in southwestern Europe) as common through all of northern Africa; it also ranges throughout southeastern Europe (southern Italy and Sicily eastwards), the Near and Middle East, Asia Minor, and southern Russia into India.

Ecologically, both forms are largely or entirely restricted to steppe lands, semidesert areas, and oases. While populations of each are usually separate and distinct on any homogeneous herd of domestic animals, a small proportion of interbreeding does occur in certain areas (see below). The subspecies *anatolicum* is definitely much more uniformly distributed than *excavatum* and generally consists of larger populations. In Egypt, as already stated, we find both forms on camels and cattle in desert and semidesert areas, but the subspecies *excavatum* never occurs on domestic animals restricted to the cultivated, nondesert Nile Valley and Delta, where the subspecies *anatolicum* is common.

Immature stages of the subspecies *anatolicum* almost without exception parasitize only hares and larger domestic animals while immature stages of the subspecies *excavatum* parasitize only smaller animals such as insectivores, rodents, and hares. Adults of the subspecies *excavatum* are considerably more common on camels in the deserts of Egypt and Libya than those of its related subspecies.

The subspecies *excavatum* breeds (mates) on its hosts in Egypt during all seasons of the year and especially during the cooler months when most members of local populations of the subspecies *anatolicum* are dormant, hiding away in cracks and crevices as either nymphs or adults.

It is noteworthy that *H. a. anatolicum* is widely distributed and studied in Russia but that the life cycle and biology of *H. anatolicum excavatum* remain unreported by Soviet workers. Both forms may undergo either a two-host or a three-host type or life cycle on the same experimental animals. Factors influencing this developmental variation, common in some *Hyalomma* species and apparently absent in others, remain to be discovered. The life cycle of the subspecies *excavatum* under experimental conditions is reported above, apparently for the first time.

Consideration of *anatolicum* and *excavatum* presently as allopatric (i.e., geographically isolated) subspecies is based on the following facts. (1) The geographical range of the two is similar but not equal, *excavatum* frequently being absent in large areas where *anatolicum* is common (i.e., Upper Egypt, eastern Saudi Arabia, Iraq, India, Daghestan, Uzbek S.S.R., etc.). (2) Where popu-

lations of the two forms meet, they interbreed in the usually fairly wide zone of contact. The incidence of such hybridization, as demonstrated by large samples (over 1,000 males) from several areas, varies locally from 2 percent to somewhat less than 20 percent. We believe that this higher rate is due entirely to one artificial factor, large herds of widely-traveling domestic camels and cattle. Primitively, these two forms probably arose as a result of ecological isolation. After centuries of transport on widely ranging domestic animals, some populations show some degree of intergradation. Nowhere in their extensive range are we aware that these forms violate or even closely approach the upper limit of the "75 percent rule" for designation of subspecies (see Mayr, Linsley, and Usinger, 1953). However, the extremely variable results obtained by Pervomaisky (1954) suggest that he has encountered one or more populations<sup>2</sup> where hybridization is rather more common than among most African-Asiatic populations.

#### ACKNOWLEDGMENTS

We are grateful to Mr. Glen M. Kohls of the Rocky Mountain Laboratory for the privilege of studying material in the Schulze collection and considerable numbers of specimens from Turkey. To Mr. E. Browning and Dr. G. Owen Evans we also owe thanks for the privilege of studying large collections of the British Museum (Natural History). Dr. J. Tendeiro, Professor O. Starkoff, and Dr. G. Blanc also kindly provided important specimens and data for this report.

In consideration of the rather delicate taxonomic considerations surrounding the present study, we have referred the manuscript to several specialists whose comments are much appreciated; these are Mr. G. Kohls and Dr. C. B. Philip (Hamilton), Professor G. V. Serdyukova (Leningrad), Dr. C. Sabrosky (Washington, D. C.), Professor J. Belkin (Los Angeles), Dr. J. Tendeiro (Lisbon), Professor O. Starkoff (Rome), Dr. G.

<sup>2</sup>Dr. R. A. Ward, who read this manuscript after it was submitted for publication, writes "... the only conclusion that I can draw is that *H. anatolicum* and *H. excavatum* are distinct species. Your taxonomic and biological data all tend to support this contention. The only criterion for subspeciation indicated in your paper is in respect to areas of hybridization. And these I would interpret [as] areas of introgressive hybridization ... where gene flow has occurred or is now occurring between two different species. ... Your material provides the first case of introgression in ticks and should be designated as such."

Dr. Ward's contention may be entirely correct, and we hope either to prove it or disprove it by continued rearing experiments. Owing to the length of the tick life cycle, 2 or 3 years of effort will be required for this purpose. At the present time, the fact that two taxonomically differing forms do occur in nature is important for the epidemiologist to know; the exact taxonomic level can be determined when more details become available.

Theiler (Onderstepoort), and Dr. P. Johnson (Washington, D. C.).

Mr. Sobhy Gaber has given invaluable assistance in the rearing experiments. The illustrations are the work of Mr. R. Strekalovsky.

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## THE INFLUENCE OF MOONLIGHT ON LIGHT-TRAP CATCHES OF MOSQUITOES<sup>1</sup>

MAURICE W. PROVOST<sup>2</sup>

### ABSTRACT

Light-trap catches of mosquitoes representing seven genera were shown to average six times greater near new moon than near full moon. Nonattractant air sampling revealed no such lunar periodicity. The light-trap lunar periodicity resembles that reported for noctuid moths

and probably reflects merely the cycle of contrast between light and background illumination as the moon passes through its phases. The moon-determined night illumination pattern is superimposed on night activity patterns peculiar to mosquitoes by species and sex.

The New Jersey light trap (Headlee 1932; Mulhern 1942) was developed specifically for mosquito sampling and has been extensively used throughout the world in both mosquito control and research. Its collections are so readily affected by variable factors residing in the trap itself, in the weather, in the environment generally, and especially in the mosquitoes, that they are never strictly proportional to the mosquito population. It follows then that the value of light-trap collections is proportional to what is known of the trap's abilities, limitations and eccentricities. Of the many environmental factors which affect the size of light-trap collections one of the most important is moon phase. Yet this effect is so easily swamped and masked by others that most trap operators seldom detect it. It is therefore necessary at once to emphasize that the moon-phase effect, in spite of its great magnitude, can be exposed and analysed only on the basis of a very large mass of operational data gathered over many months and preferably years. This is equally necessary in trying to establish whether the moon-phase effect is a matter of mechanical efficiency or a reflection of altered behavior in the insects, a problem this paper will attempt to elucidate.

In 1936 C. B. Williams, of the Rothamsted Experimental Station (England), published a very searching analysis of the moonlight influence on activity in nocturnal insects, particularly noctuid moths. With the Rothamsted light trap (Williams 1935), he demonstrated a ratio of noctuid captures between new and full moon of 3:1 on clear nights and 2:1 on cloudy nights. He found similar but less pronounced periodicities in other insect groups and none in some, and concluded that the moon effect was greatest in insects having their maximum activity at midnight and least in those flying chiefly at dusk or dawn. There remained unexplainable features, however, and he surmised that the moon effect "is probably a physiological effect on the activity of the insects and not merely due to reduction in the efficiency of the light trap when the moon is shining" (Williams 1936, p. 389). He later (Williams 1940) refined his analysis of asymmetries in the moon effect and correlated these with asymmetries in the times of rising and setting of the moon. Again at Rothamsted in 1940 a suction trap showed lunar periodicities in captures of Diptera (Williams and Singh 1951) and since light attraction was not involved it was concluded "that the moonlight must have a definite effect on nocturnal insects, and that the low catches in a light trap at full moon are not merely due to a physical reduction of the efficiency of the trap" (p. 853). However, later and more exhaustive experiments with suction traps failed to duplicate the 1950 results, forcing the conclusion that:

<sup>1</sup>Contribution No. 65, Florida State Board of Health, Entomological Research Center, Vero Beach, aided by grant E-1492, National Institutes of Health, U. S. Public Health Service. Accepted for publication September 18, 1958.

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